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FOR

TRANSFLECTIVE COLOR RECOVERY

Inventor

Serge Bierhuizen

InFocus Corporation

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Schwabe, Williamson & Wyatt, P.C.
1211 SW Fifth Avenue, Suites 1600-1900
Portland, OR 97204-3795
(503) 222-9981
fax (503) 796-2900

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TRANSFLECTIVE COLOR RECOVERY

Related Applications

[0001] This application is a continuation-in-part of application serial number 10/150,223, filed May 17, 2002 and application serial number 10/150,438, filed May 17, 2002.

Field of the Invention

[0002] Disclosed embodiments of the invention relate to the field of color video projection systems. More specifically, disclosed embodiments of the invention relate to color recycling in color video projection systems.

Background

[0003] Recent developments in faster switching liquid crystal and digital micromirror technologies have made single panel projection systems possible. These projection systems may use sequential or scrolling color filters to scroll color across the display, updating the display one row at a time instead of updating the entire frame. This approach is particularly useful with some liquid crystal displays that have slow response times. Color wheels and drums have been developed to provide bands of color that scroll across the display as the rows of the display are updated. These color filters effectuate the transmission of light in only one color (typically red, green, or blue) to one section of the display. The display, based on image data, selectively transmits portions of the various single color light. A transmissive display may do this by reflecting, or absorbing, light of one polarization while transmitting light in another. Non-transmitted light, due to the color filter or display, is lost in the system creating inefficiencies. This results in a dimmer display or requires a brighter light source. In a projector, a dimmer display is more difficult to view, while a brighter light source increases the power consumption, the amount of heat that needs to be dissipated, and the cost of the projector system.

Brief Description of the Drawings

[0004] Embodiments of the invention are illustrated by way of example and not by way of limitation in the figures of the accompanying drawings, in which the like references indicate similar elements and in which:

[0005] **Fig. 1** is a simplified pictorial plan view of an illumination arrangement, including a color recycling subsystem, providing light to a display, in accordance with an embodiment of the present invention;

[0006] **Figs. 2A** and **2B** show a diagram of light produced by a scrolling transflective color filter as it might be focused on a display at two points in time, in accordance with an embodiment of the present invention;

[0007] **Fig. 3** is a cross-sectional view of a transflective color filter, in accordance with an embodiment of the present invention;

[0008] **Fig. 4** is a simplified pictorial plan view of multiple variations of an illumination arrangement, including an optical integrator in the color recycling path, providing light to a display, in accordance with embodiments of the present invention;

[0009] **Fig. 5** is a simplified pictorial plan view of multiple variations of an illumination arrangement including a color recycling path that couples the recycled light back into the direct light path, in accordance with embodiments of the present invention;

[0010] **Fig. 6** is a simplified pictorial plan view of an illumination arrangement, including a color recycling subsystem with a relay optical arrangement and a mirror, providing light to a display, in accordance with an embodiment of the present invention;

[0011] **Fig. 7** is a simplified pictorial plan view of an illumination arrangement, including a color recycling subsystem with a relay optical arrangement and an optical

integrator, providing light to a display, in accordance with an embodiment of the present invention;

[0012] **Fig. 8** is a simplified pictorial plan view of an illumination arrangement, including a color and polarization recycling subsystem, providing light to a display, in accordance with an embodiment of the present invention; and

[0013] **Fig. 9** is a simplified pictorial plan view of a video projection system showing a video unit coupled to a projection system that includes image projection optics and an illumination arrangement, in accordance with an embodiment of the present invention.

Detailed Description of Embodiments of the Invention

[0014] Embodiments of the present invention relate to multimedia color projectors, and more particularly to color and/or polarization recovery in an illumination arrangement.

[0015] In the following detailed description, reference is made to the accompanying drawings which form a part hereof wherein like numerals designate like parts throughout, and in which is shown by way of illustration specific embodiments in which the invention may be practiced. It is to be understood that other embodiments may be utilized and structural or logical changes may be made without departing from the scope of the embodiments of the present invention. It should also be noted that directions such as up, down, back and front may be used in the discussion of the drawings. These directions are used to facilitate the discussion of the drawings and are not intended to restrict the application of the embodiments of this invention. Therefore, the following detailed description is not to be taken in a limiting sense, and the scope of the embodiments of the present invention are defined by the appended claims and their equivalents.

[0016] **FIG. 1** illustrates a simplified pictorial plan view of an illumination arrangement **6**, including a recycling subsystem **18**, providing light to a display **14**, in accordance with an embodiment of the present invention. A light source **8** may be optically coupled to a transflective color filter **12**, such that at least a portion of the light produced by the light source **8** is received by the transflective color filter **12**. The transflective color filter **12** may then transmit portions of the light to the display **14** while reflecting other portions. The recycling subsystem **18** may be optically coupled to the transflective color filter **12**, such that it receives the reflected light. The reflected light may then recycled by the recycling subsystem **18** and reintroduced to the transflective color filter **12**.

[0017] The light source **8** may be of a conventional design or any other design depending on the particular application. In one embodiment the light source **8** may include an arc lamp mounted at the focus of an elliptical reflector. An optional meniscus lens (not shown) may be placed between the elliptical reflector and the transflective

color filter **12** to concentrate the light and reduce the cone angle. Embodiments of this invention could employ either converging (shown) or diverging light sources to accommodate for the downstream optical configuration. The white light may propagate along an incidence axis **10** and impinge upon the face of the transflective color filter **12** with an incidence angle θ. The transflective color filter **12** may transmit light within certain passbands **13** while reflecting light outside of these passbands **16**. The transmitted light **13** may illuminate the display **14**. While this embodiment is particularly suitable for a projection system using a transmissive display such as a liquid crystal display or a liquid crystal light valve, different embodiments could use any other reflective or transmissive display with appropriate modifications, including re-imaging the light onto a reflective panel.

[0018] The reflected light may travel along a reflectance axis **16** towards the input **18a** of the recycling subsystem **18**. The input **18a** may be located on the reflectance axis **16**, which is non-coincident with the incident axis **10**, so that the optical components required to collect the reflected light do not interfere with the incident light. The reflectance axis **16** and the incident axis **10** intersect at the face of the transflective color filter **12**.

[0019] The recycling subsystem **18** may redirect the reflected light back towards the transflective color filter **12** as recycled light along a recycling axis **20**. In various embodiments, the recycling axis **20**, i.e., the axis upon which the recycled light is reintroduced to the transflective color filter **12**, may be coincident with the reflectance axis **16**, the incident axis **10**, or neither axis depending on the properties of the recycling subsystem. Upon reintroduction, some of the recycled light **20** may be transmitted through to the display **14**. In this embodiment, the recycled light **20** may exit through the recycling subsystem input **18a**, however other embodiments could provide separate input and outputs for the recycling subsystem **18**.

[0020] At the display **14**, the angular intensity distribution, i.e., the angular spread of the light transmission as a function of the incident angle **Θ**, produced by the light source **8** into the entrance pupil of the projection lens may look like two elongated hot spots above one another. The upper hot spot may come from the light from the incident axis **10**, while the lower hot spot may be the light recycled back along the reflectance

axis **20**. The light is spread over horizontal directions orthogonal to the two vertically aligned spots (such a horizontal line can be regarded as a line going through the plane of the page in the figures). The two hot spots correspond to a central area with an average incident angle Θ close to perpendicular to the display **14**. If the transflective color filter **12** and display **14** are properly selected and positioned, this elliptical spreading property of the illumination can be exploited to improve the efficiency of the system. For example, in an embodiment where the display **14** includes a digital micromirror device we can make use of the non-symmetrical pupil filling by appropriate alignment of the tilt direction of the micromirrors, which often limits the pupil size in one direction (in order to get high contrast). The pupil asymmetry may be matched with the direction orthogonal to the mirror's tilt direction to take advantage of this property.

[0021] **Figs. 2A** and **2B** show a diagram of light produced by a scrolling transflective color filter **12** as it might be focused on the display **14**, in accordance with one embodiment of this invention. A light field **26** may comprise scrolling bands of multiple colors, e.g., primary colors, which correspond to the segments of the scrolling transflective color filter **12**. In **Fig. 2a**, the light field **26** is segmented into three bands, a red band **28**, a green band **30**, and a blue band **32**. The bands move across the light field so that in **Fig. 2b**, which shows the same light field **26** at a later time, the bands have moved down the light field. The blue band **32** has scrolled partially off the bottom of the light field and has partially reappeared at the top. This approach allows all but a few of the rows of the display to be illuminated almost constantly. Only the rows that are changing to the next color do not contribute to the image. Black bands (not shown) can be placed between the colored bands to prevent rows that are changing from affecting the display **14**.

[0022] The transflective color filter **12** may be used to synchronize the light source with the scrolling display **14** in order to illuminate each row of the display **14** with the appropriate color at the appropriate time. Examples of transflective color filters **12** that may be suitable for this type of application include but are not limited to rotating prisms, a rotating color drum, a sequential color recapture wheel, and a band modulation filter. They all have the characteristic that a number of colors, usually the

three primary ones, e.g., red, green and blue, may be transmitted at one time to the display **14**.

[0023] **Fig. 3** shows a cross-sectional view of the transflective color filter **12** in accordance with one embodiment of this invention. In this embodiment the transflective color filter **12** includes a red color passband **36**, a green color passband **38** and a blue color passband **40**. These color passbands allow a range of frequencies corresponding to a particular color to pass through the filter while reflecting the frequencies outside of these ranges. White light **42** traveling along the incidence axis, strikes the face of the transflective color filter **12**. The red passband **36** may transmit light in the red color band **44** and reflect cyan light **46**, or a combination of blue and green. The green passband **38** may transmit light in the green color band **48** and reflect magenta light **50**, a combination of blue and red. And finally the blue passband **40** may transmit the light in the blue color band **52** and reflect yellow light **54**, a combination of red and green.

[0024] **Fig. 4** is a simplified pictorial plan view of multiple variations of an illumination arrangement, including an optical integrator in the color recycling path, providing light to a display, in accordance with embodiments of this invention. In the first embodiment depicted in **Fig. 4a**, a light source **8** similar to the one discussed with relation to **Fig. 1**, causes incident light to impinge upon the transflective color filter **12**. Portions of the light containing color wavelengths that match the associated color passband are transmitted, while wavelengths outside of these passbands are reflected along the reflectance axis toward the recycling subsystem **18**. In embodiments comprising R,G,B passbands, C,M,Y may be the respective reflected light.

[0025] The recycling subsystem **18** of this embodiment may include an optical element **60** at its input, an optical integrator **58**, and a mirror **62**. The reflected light is imaged by the optical element **60** onto an opening aperture **58a** at the first end of an optical integrator **58**. The optical integrator **58** of this embodiment may be a solid glass light-integrating tunnel, which integrates the reflected light through total internal reflection.

[0026] This tunnel integrator **58**, may have a mirror **62** positioned at or near the second end **58b** of the tunnel. A mirror may be any type of reflective surface or coating that reflects the appropriate wavelengths. The mirror **62** may be a separate optical

component or it may be a coating applied to the second end **58b** of the tunnel. The mirror will redirect the light back towards the opening aperture **58a**. The bands of C,M,Y light may become sufficiently integrated as they travel twice the length of the tunnel before exiting. The recycled integrated light may pass back through the optical element **60** to be reintroduced to the transflective color filter **12**, giving the light a second opportunity to be transmitted. In another embodiment the opening aperture **58a** of the recycling integrator **58** may receive the reflected light directly from the transflective color filter **12**, without going through the optical element **60**.

[0027] In the above embodiment, the incident light from the light source **8** is not integrated, which may be useful in video projection systems, as the perceived brightness is larger with the increased center peak brightness. The homogenized recycled light may then increase the intensity in the corners.

[0028] **Fig. 4b** depicts an embodiment that includes an optical integrator **56** on the incident light path. This optical integrator **56** may be an integrating tunnel that has a tapered cross-sectional area to suit particular applications. A typical tunnel has a rectangular cross-section and is either straight or smaller at its entrance near the light source and larger at its exit. An output aperture of the optical integrator **56** may have an aspect ratio that matches the downstream display's aspect ratio, that is, the ratio between the width and the height of the image. Although this embodiment describes a glass rod integrator, other embodiments of this invention may use a double flyseye lens integrator or any other sufficiently effective integration device that provides a substantially uniform light distribution upon exiting the integrator.

[0029] In various embodiments, outlet apertures of the optical integrator **56** may have a cross-sectional aspect ratio that provides a projection display format that is compatible with conventional display standards. Some examples of display standards include SVGA (Super Video Graphics Array), XGA (Extended Graphics Array), UXGA (Ultra XGA), WUXGA (Widescreen Ultra XGA), and HDTV (High Definition Television). These display standards are often a combination of resolution, color depth measured in bits, and refresh rate measured in hertz. SVGA, XGA, and UXGA all have aspect ratios of 4:3. HDTV has an aspect ratio of 16:9 and WUXGA is 16:10.

[0030] **Fig. 4c** depicts an embodiment similar to the one discussed in **Fig. 4b**, however this embodiment includes an imaging lens **61** used to focus the output aperture of the optical integrator **56** onto the display device **14**.

[0031] **Fig 5.** is a simplified pictorial plan view of various embodiments of an illumination arrangement, including a color recycling path that couples the reflected light back into the incident light path. Specifically in the embodiments depicted by **Figs. 5a, 5b,** and **5c** the recycling subsystem **18** recycles the reflected light by coupling it back into the optical integrator **56** on the incident axis using a series of reflective devices **64** and **68**. Referring to **Fig. 5a**, the recycling subsystem **18** takes advantage of the 'hole' in the center of the illumination from the light source **8**. Arc lamp illumination often has a "hole in the middle" effect due to arc lamp shadowing off of the elliptical reflector. This embodiment utilizes that effect by placing a small reflector **68** in the "hole" to re-introduce the recycled light into the optical integrator **56** on the incident axis, and ultimately the transflective color filter **12**. In this architecture the light may be continually recycled through the recycling subsystem until it is transmitted to the display **14**. Furthermore, specifically designed optics may be used to optimize the angular properties of the recycled beam for to increase the amount of recycled light.

[0032] An alternative embodiment, depicted in **Fig. 5b**, shows the reflector **68** being placed close to the entrance of the optical integrator **56**, only slightly reducing the amount of entrance light from the light source **8**. Although these embodiments depict using reflector mirrors **64** and **68** to direct light through the recycling subsystem, other embodiments could use other types of light directing technologies, e.g. optical fibers.

[0033] The embodiment depicted in **Fig. 5c** is similar to **Fig. 5b**, however the recycling subsystem **18** includes an optical integrator **57** to integrate the light reflected by the transflective color filter **12**. The optical integrator **57** may also be incorporated into the **Fig. 5a** embodiment.

[0034] The embodiments depicted by **Fig. 5** show that the reflected light is coupled back into the integrator **56** through the end of the integrator **56**. However, in an embodiment where the integrator **56** is a solid glass tunnel, it may be possible to introduce the light through the sides of the tunnel as well.

[0035] **Fig. 6** is a simplified pictorial plan view of an illumination arrangement, including a color recycling subsystem **18** with a relay optical arrangement **74** and a mirror **82**, providing light to a display **14**, in accordance with one embodiment of this invention. In brief, the embodiment depicts a relay optical arrangement **74** with various sections that are involved in both the incident and reflectance paths.

[0036] In particular, the light source **8** directs light into an optical integrator **56**, such as a tunnel discussed above, which integrates the light and gives it a desired cross-sectional shape. The light exiting the tunnel **56** may be substantially telecentric due to the design of the light tunnel. However, any other source of telecentric or non-telecentric illumination can be used instead of the light source/tunnel combination discussed in this embodiment. Light from the tunnel **56** may enter an imaging lens **72** and then a relay optical arrangement **74**, consisting of a relay lens in this embodiment. The two lenses **72** and **74** may be designed to create a telecentric image of the illumination from the light source at the display. The imaging lens **72** makes an intermediate image of the light source at an intermediate position **76** between the two lenses **72** and **74**. The relay lens **74** then creates an image of the output of the tunnel **56** onto the display **14**, with the intermediate pupil **76** imaged at infinity. Appropriate modifications can be made to the optical arrangement to accommodate the differences in light sources, optical integrators, or display sizes of various embodiments.

[0037] These lenses **72** and **74** may be singular or multiple optical components of various types, as appropriate. In one embodiment the lenses may be conventional spherical lenses. Additionally, various aspheric, diffractive, or Fresnel surfaces may be included as may be desired to achieve cost and size goals for the system. Prisms, mirrors, and additional corrective elements may also be added as appropriate to fold, bend or modify the illumination light for the intended application.

[0038] Considering the focal lengths involved in the embodiment of **Fig. 6** in more detail, the imaging lens **72** has a focal length **f1** that equals the distance from its focal plane to the exit aperture of the tunnel **56**. Accordingly, it makes a lamp image and has its exit pupil at the position **76** that is a distance **f1** away. The first section of the relay lens **78** has a focal length of **f2** and is placed at that distance, **f2**, from the intermediate position **76** and from the display **14**. The first section of the relay lens **78** re-images the

pupil from the imaging lens **72**, i.e. the lamp image at intermediate position **76**, at infinity for telecentric illumination at the display **14**. The first section **78** may be designed to image the exit aperture of the tunnel **56** at the display **14**. Light travelling from the first section **78** to the display **14** will do so along an incident axis, similar to the one described with reference to **Fig. 1**.

[0039] As can be seen in **Fig. 6**, the imaging lens **72** is centered on the tunnel **56**. In other words, the optical axis of the imaging lens **72** is aligned with the center of the tunnel **56**, however, other configurations are possible. The relay lens **74** may be de-centered with respect to the tunnel **56** and light source **8**. This causes the illumination at the display **14** to be off-axis, filling half the system's Étendue. The relay lens **74** is decentered to the point that its optical axis is near the edge of or completely outside of the optical path of the image of the source **8**. This de-centering allows for the input to the recycling subsystem **18** to lie on a different axis then the incident axis. The relay lens **74** is, however, roughly centered about the display **14** as is shown in **Fig. 6**. This means that the light from the light source **8** arrives at the imaging lens **72** decentered with respect to the display **14** but the relay lens **74** centers the image of the light on the display **14**.

[0040] The lenses need not be exactly centered with respect to the tunnel **56** or the display **14**, as shown in the figures. Each one can be moved slightly if the other is so adjusted. In addition, if the transflective color filter **12** is placed at an angle then the relay lens **74** can be moved accordingly. The placement of the lenses in the illustrated embodiment may reduce the dimensions of the optical arrangement, however, the elements can be moved in a variety of different ways to meet particular size and form factor constraints of a specific embodiment.

[0041] As the incident light impinges upon the transflective color filter **12**, some color bands may pass through (e.g. R, G, B), while others (e.g. C,M,Y) may be reflected along a trajectory following a reflectance axis, similar to **Fig. 1** discussion. In the embodiment depicted by **Fig. 6**, the recycling subsystem **18** consists of a second section of the relay lens **80** and a mirror **82**. In this embodiment the second section of the recycling optical arrangement has a focal length equal to the first section **f2**. In this embodiment the mirror **82** may be placed at the imaging focus of the second section of

the relay lens **80**, which is directly above the intermediate focus discussed earlier. In other embodiments the two sections of the relay optical arrangement **74** could have different focal lengths, and therefore the mirror **82** positioning would be adjusted accordingly.

[0042] The two sections of the relay lens **74** do not have to be mutually exclusive, as there can be some overlap as shown in the figure. The incident axis for certain light rays may pass through the same area of the relay lens **74** as the reflectance axis for other light rays. However, in this embodiment, each particular light ray will travel from the first section of the relay lens **78** on its incident axis, and will travel to the second section of the relay lens **80** on its reflectance axis. This will be possible by keeping the angle of incidence, Θ, less than 90 degrees. This can be done by providing the origin of the incident axis below the point that the incident axis intersects with the transflective color filter **12**, as shown with the off-lens construction described above. This may also be accomplished by tilting the transflective color filter **12**.

[0043] In one embodiment, the mirror **82** may be tilted slightly such that it will reflect the C,M,Y bands along a different trajectory back towards the second section of the relay lens **80**. Therefore, the second section of the relay lens **80** will reintroduce the C,M,Y bands to the transflective color filter **12** at an area different than they were originally reflected from. Reintroduction at a different section of the transflective color filter **12** may result in an increase in transmitted light through the passbands. In an embodiment, the mirror **82** may be designed such that light rays reflected from the bottom portion of the transflective color filter **12** will be reflected from the mirror **82** at an upward angle so that the light is reintroduced near the top portion of the transflective color filter **12**. In other embodiments of the present invention, specific calibration methods known in the art may be employed to increase the efficiencies of a particular optical architecture.

[0044] **Fig. 7** is a simplified pictorial plan view of an illumination arrangement, including a color recycling subsystem with an optical integrator **92**, providing light to a display **14**, in accordance with an embodiment of this invention. In this embodiment the functionality of the illumination arrangement is similar to **Fig. 6**, however, the mirror **82** is replaced with a fold mirror **86**, a lens **88**, and an optical integrator **92**. The optical

integrator **92** may be similar to the optical integrator **58** in **Fig. 4**. The lens **88** may focus the C,M,Y color bands on the input aperture of the optical integrator **90**. A mirror **94** may be placed at or near the far end of the optical integrator **92** so that light is redirected back substantially along the original recycling trajectory until the integrated light is reintroduced on the transflective color filter **12**. Portions of the recycled integrated light may be transmitted through the passbands of the transflective color filter **12** and impinge upon the display **14**.

[0045] **Fig. 8** depicts an embodiment of this invention that combines both polarization recovery and color recycling. This embodiment may contain a similar optical architecture as **Fig. 6**, however, this embodiment permits polarization recycling by the addition of a transflective polarizer **98**, mirror **102**, and a quarter wave plate **104**. One polarization state (usually P-polarization) may be transmitted through the transflective polarizer **98** to the transflective color filter **14**.

[0046] P-polarized light rays are indicated in the drawing figures by short-length transverse lines intersecting a line representing a light propagation path. The lines suggest a polarization vector that is vertically aligned in the plane of the drawing sheet. The other polarization state (usually S-polarization) is reflected towards a mirror **102**. S-polarized light rays are indicated in the drawing figures by small open circles connected together by a line representing a light propagation path. The circles suggest a polarization vector normal to the plane of the drawing sheet.

[0047] The mirror **102** may then reflect the S-polarized light back to the transflective polarizer **98**, which may reflect it in the direction of the source. With the off-set lens construction it may pass through a quarter wave plate **104** that rotates the polarization direction to substantially the P-polarization, and may then be reflected by a mirror **82** back toward the transflective polarizer **98** where it may be transmitted to the transflective color filter **12**.

[0048] The quarter wave plate **104** or some other polarization conversion device may be placed anywhere between the mirror **82** and the transflective polarizer **98**. This could also be a quarter-wave film or coating placed on the mirror. The system could include a polarizing analyzer behind the display, such as an iodine-based PVA (poly-vinyl alcohol) film, or a wire grid polarizer to filter out any stray S-polarized light,

enhancing contrast. Analyzers and polarizing filters may also be placed in other locations of the system as may be appropriate for a particular application or illumination system.

[0049] The transflective polarizer **98** may be, e.g. a prism-type or a plate-type polarizing beam splitter, or any other type of device which will allow substantially all the light of one polarization state to pass, while reflecting substantially all the light of another, substantially perpendicular, polarization state. Examples of the plate-type PBS include, but are not limited to, a wire-grid polarizer, a cholesteric polarizer, a polymer film stack, or a dielectric coating stack.

[0050] Many types of transflective polarizers and polarizing beam splitters may have angular dependent transmissive ranges that differ between orthogonal axes. In one axis, e.g. the horizontal, a greater range of incident light angles may be transmitted than in the other orthogonal axis, e.g. the vertical. The elliptical hotspot properties discussed above may be exploited by properly positioning the polarizing materials so that the axis of the greater angular transmission characteristic or the greater angular acceptance is aligned with the angular intensity distribution of the illumination. Stated another way, the transmissivity of the system is improved by matching the direction of the elongation of the hot spots to the direction of the high contrast isocontrast curve of the particular polarizer. This may increase efficiency that may be accompanied by a commensurate increase in brightness and contrast.

[0051] **Fig. 9** is a simplified pictorial plan view of a system including a video unit **110** coupled to a projection system **112**, in accordance with an embodiment of the present invention. In this embodiment a video unit **110** transmits video signals to the projection system **112**, which includes image projection optics **114** and an illumination arrangement **116**. The illumination arrangement **116** may be similar to any one of the various embodiments described under the teachings of this invention. In one embodiment the image projection optics **114** may include a transmissive liquid crystal light valve arrangement coupled to a projection lens, to image the light valve on a screen. In other embodiments the image projection optics **114** could include reflective, rather than transmissive displays. The video unit **110** may include a personal or laptop computer, DVD, set-top box (STB), video camera, video recorder, or any other suitable

device to transmit video signals to the projector. The system may be used as a projector for computer generated slides and for digital sourced imagery; however, many other applications such as games, movies, television, advertising and data display can be made.

[0052] Although specific embodiments have been illustrated and described herein for purposes of description of the preferred embodiment, it will be appreciated by those of ordinary skill in the art that a wide variety of alternate and/or equivalent implementations calculated to achieve the same purposes may be substituted for the specific embodiment shown and described without departing from the scope of the present invention. Those with skill in the art will readily appreciate that the present invention may be implemented in a very wide variety of embodiments. This application is intended to cover any adaptations or variations of the embodiments discussed herein. Therefore, it is manifestly intended that this invention be limited only by the claims and the equivalents thereof.